

daratech iDPS2002

Intelligent Digital Prototyping Strategies

by

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Contradicting Design Requirements

The need for innovative tools is apparent now more than ever as more complex design requirements are surfacing such as:

- Cost
- Performance & safety
- Quality
- Time to market & short life cycle
- Environmental impacts
- Aesthetics (wow, lust for the product, I got to have it ...)
- Major Changes in Industry's Business Model



- Cycle development time from concept to production is being compressed significantly
 - 1992: 60 months
 - 1996: 48 months
 - 2000: 18 months
- Vehicle designs are tailored to focused markets
- Vehicles are being manufactured more on a global scale
- Vehicles designed increasingly through multiple engineering sites around the world
- Need for enabling companies throughout the supply chain and extended enterprise to share information through a web-centric visualization approach



Design Process Status:

- **Great Advances in the Design Process**
 - Moving from paper drawing to electronic drawing
 - Moving from electronic drawing to 3D wire frame
 - Moving from 3D wire frame to solid modeling
 - Moving to Parametric feature based solid modeling (commodity: Granite, Para-solids, Acis, etc)
 - PDM/ERP/MRP/PLM ???
 - Still tradition and experience govern the design choices
- **What is next**
 - Integrated Product Development Process (AEE)
 - Knowledge capture and reuse (KBE)
 - Documentation of rationale for the design
 - Best practice automation (Self designed parts)
 - Collaborative design

Engineering Design and Simulation Tools

- The simulation tools such as FEA, CFD, CAM, although easier to use and better integrated with CAD, become more powerful and more complex.
- Typically by the time they provide feedback to a design that design has evolved over several iterations due to packaging, cost, availability, manufacturing, etc.
- Behavioral modeling provides *a return to simplicity* by imposing fundamental engineering rules at the CAD level.
- Behavioral modeling is a new paradigm shift in the design process empowering engineers to create optimum, innovative, requirement driven designs on their first try.

Quality – Robust Design



- **Definition of Robust Design:**
Deliver customer expectations at profitable cost regardless of:
 - customer usage
 - variation in manufacturing
 - variation in supplier
 - variation in distribution, delivery & installation
 - degradation over product life
- **Goals of Robust Design (shift and squeeze)**
 - Shift performance mean to the target value
 - Reduce product's performance variability

Statistical Design Performance Simulation?

*“ You ‘ve got to be passionate lunatics about the **quality issue** ...”*
Jack Welch

*“U.S. autos fight **poor quality reputation** ...”*
Joe Miller / The Detroit News

*“ **Product quality requires managerial, technological and statistical concepts throughout all the major functions of the organization ...”***

Josheph M. Juran

Variation (thickness, properties, surface finish,
loads, etc.) is ... ***THE ENEMY***

**DOE, Six Sigma, Statistical FEA, Behavioral
Modeling ...** ***THE DEFENCE***

Improved Quality reduced Total Cost

Cost of Defect or Failure

- Lost Customers
- Liability (R&D)
- Recalls (production)
- Rework

Examples:

Titanic

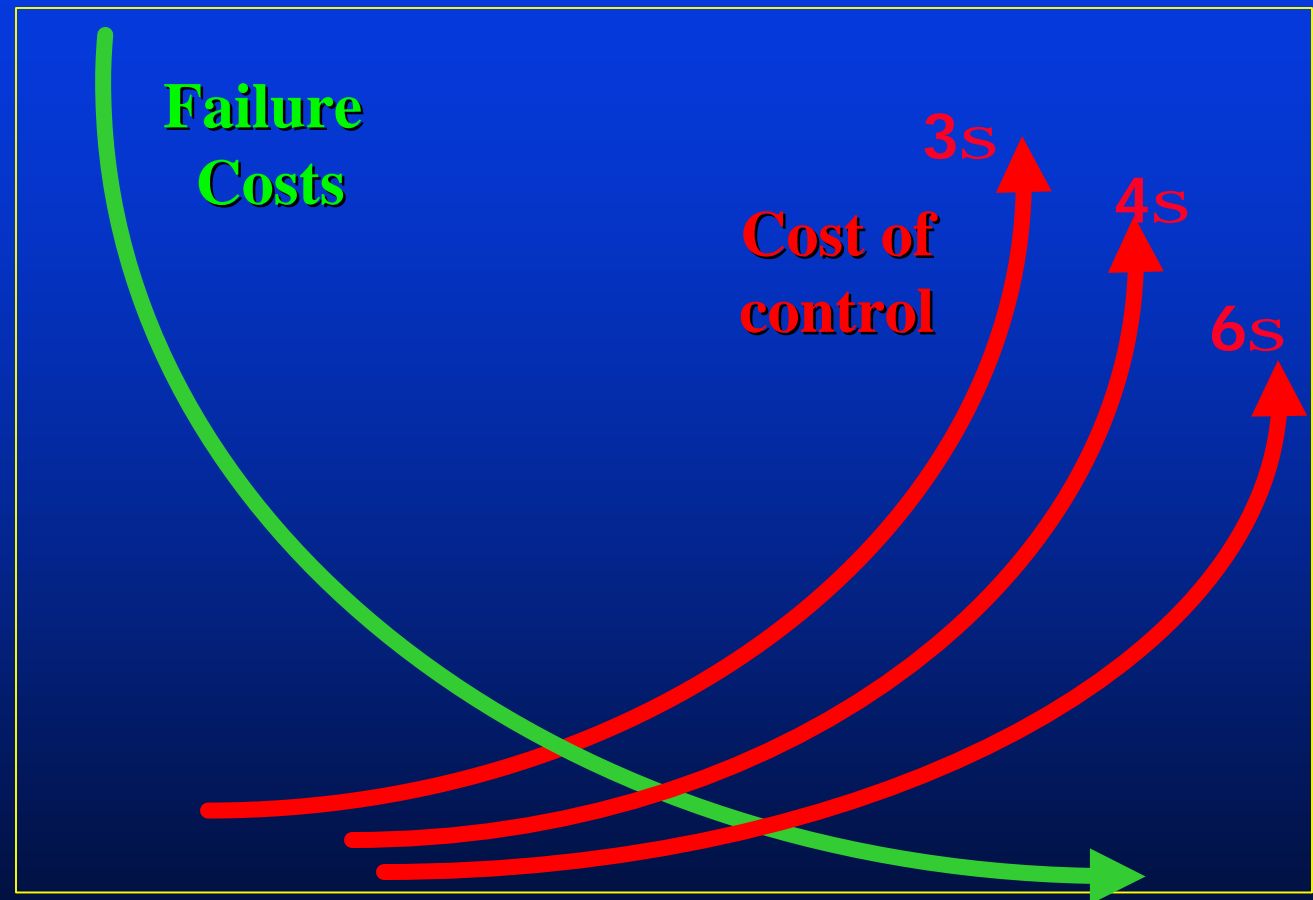
Asbestos

Breast Implants

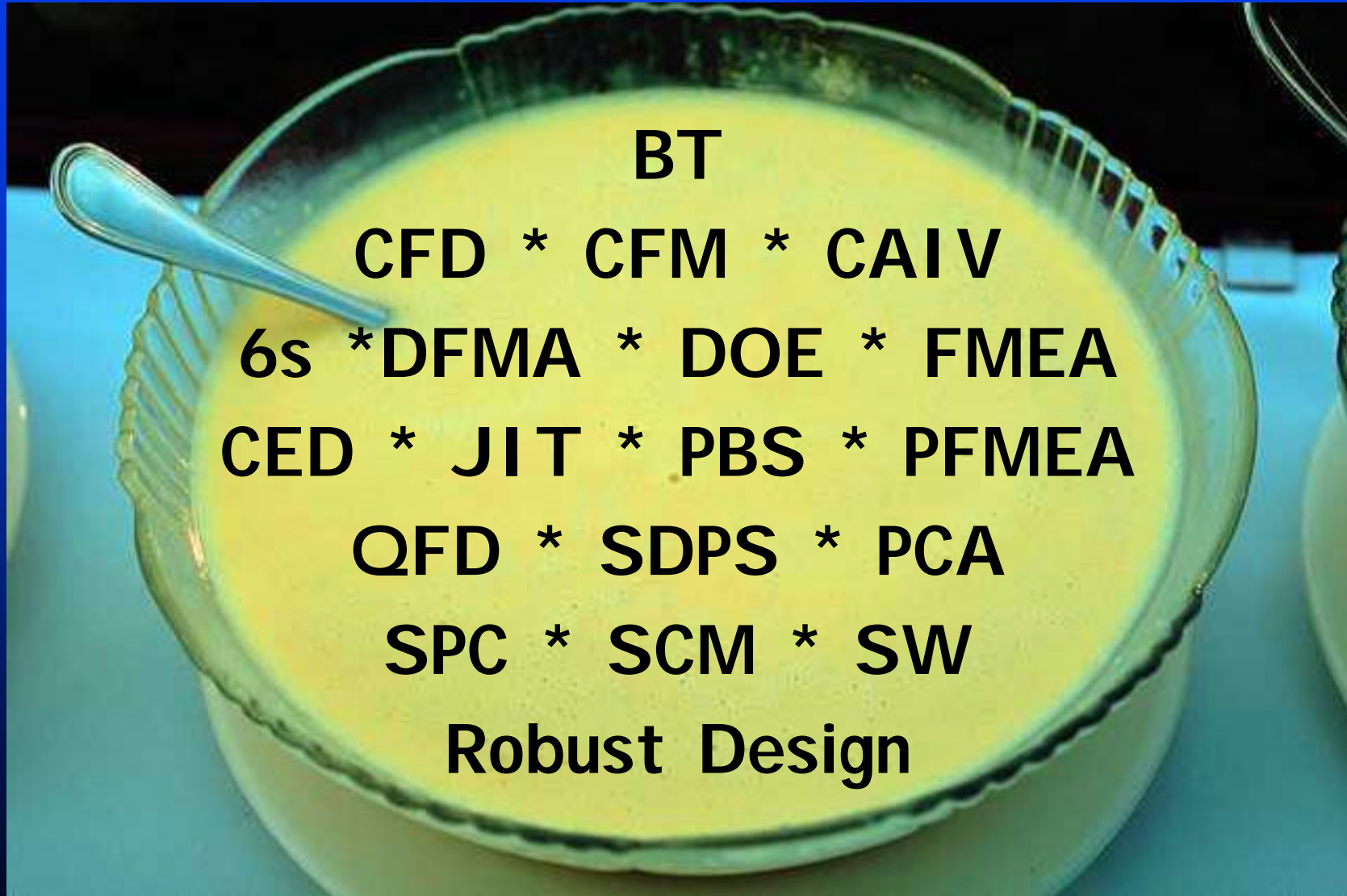
Bhopal, India

...

Cost ↑



Defect Level ←



BT

CFD * CFM * CAIV

6s * DFMA * DOE * FMEA

CED * JIT * PBS * PFMEA

QFD * SDPS * PCA

SPC * SCM * SW

Robust Design

Elements of Quality Management Process

- Agile Improvement Process
- Axiomatic Design
- Benchmarking & Benchtrending
- Catch-ball
- Cellular Manufacturing
- Continuous Flow Development
- Continuous Flow Manufacturing
- Cycle Time Management
- Defect Reduction
- Design for Manufacturing and Assembly
- Design of Experiments
- Failure Modes effects Analysis
- Cause and Effect Diagrams
- Just In Time
- Performance Based Specifications
- Process Failure Mode Effects Analysis
- Quality Function Deployment
- Robust Design
- Self-Directed Work Teams
- Statistical Design Performance Simulation
- Process Capability Analysis
- Statistical Process Control
- Supply Chain Management
- Synchronous Workshops
- Theory of Constraints
- Thinking Process Reality Trees
- Total Productive Maintenance

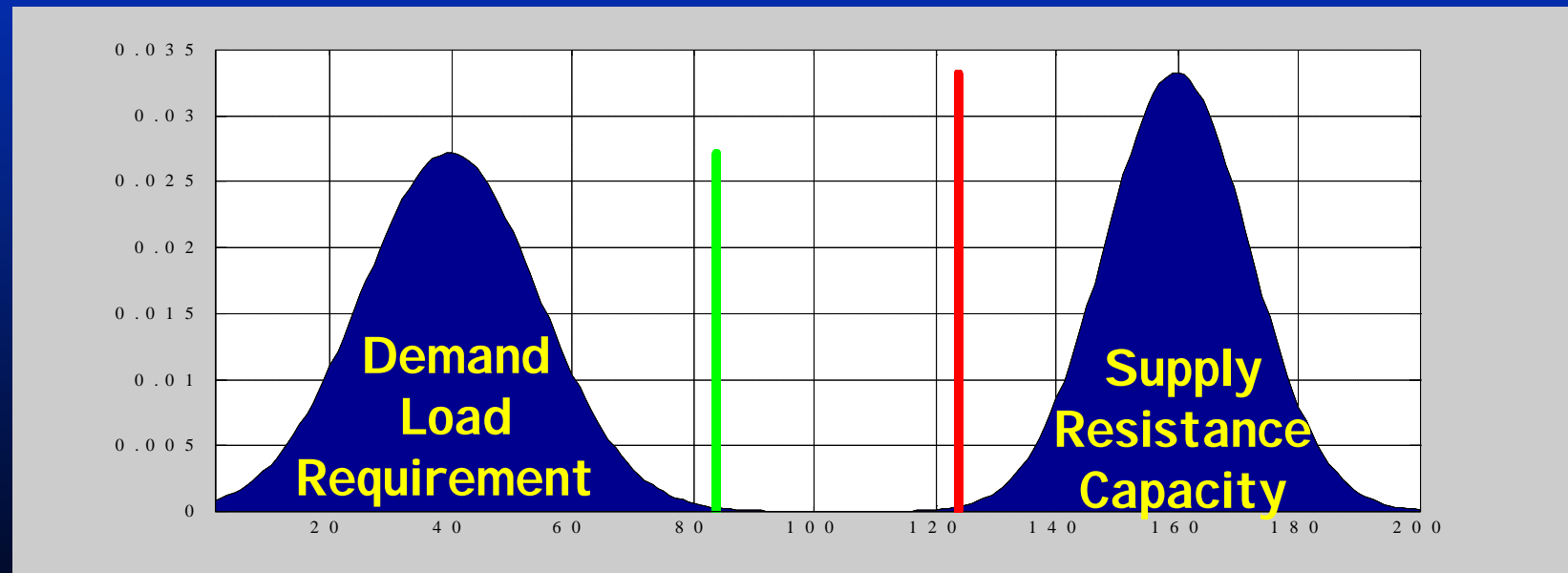
Elements of Quality Management Process



- Although all the elements of quality management process are closely connected they remain apart because they have been developed independently from each other
- Integration of these tools is critical to the organization and necessary for successful federation and robust optimization efforts

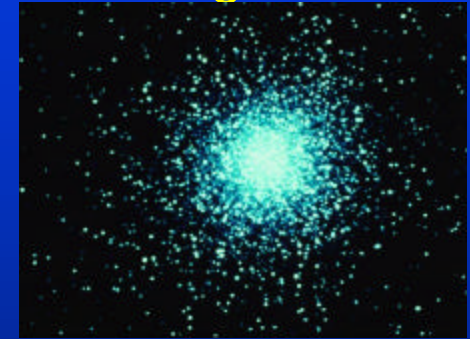


- Accounts for uncertainties through the use of empirical Safety factors:
 - Are derived based on past experience
 - Do not guarantee safety or satisfactory performance
 - Do not provide sufficient information to achieve optimal use of available resources



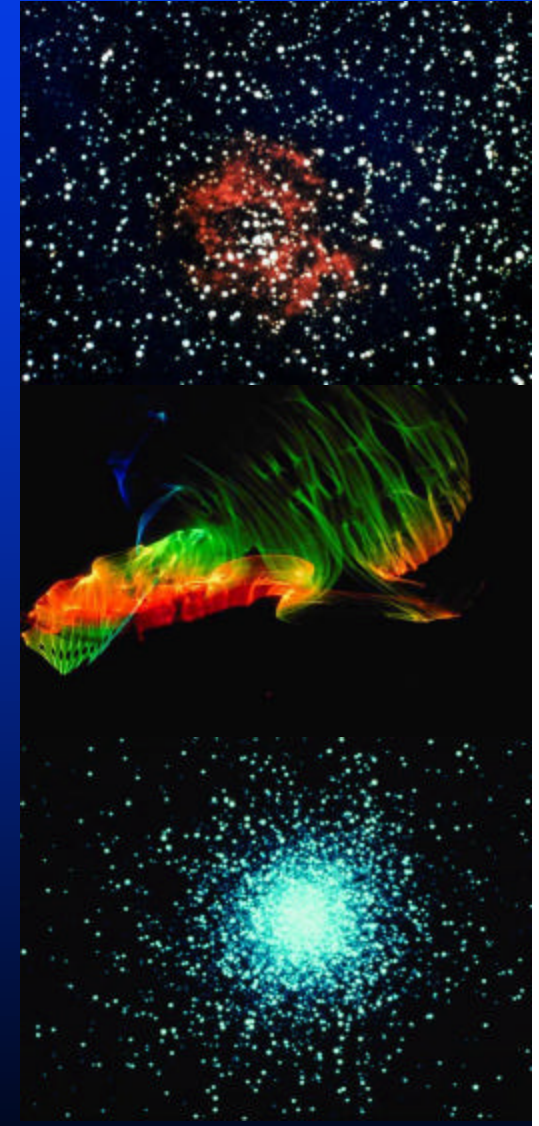
Noise & Control Parameters

- Noise parameters:
Factors that are beyond the control of the designer
 - material property variability
 - manufacturing process limitations
 - environment temperature & humidity
 - component degradation with time
 - ...
- Control Parameters:
Factors that the designer can control
 - geometric design variables
 - material selections
 - design configurations
 - manufacturing process settings
 - ...

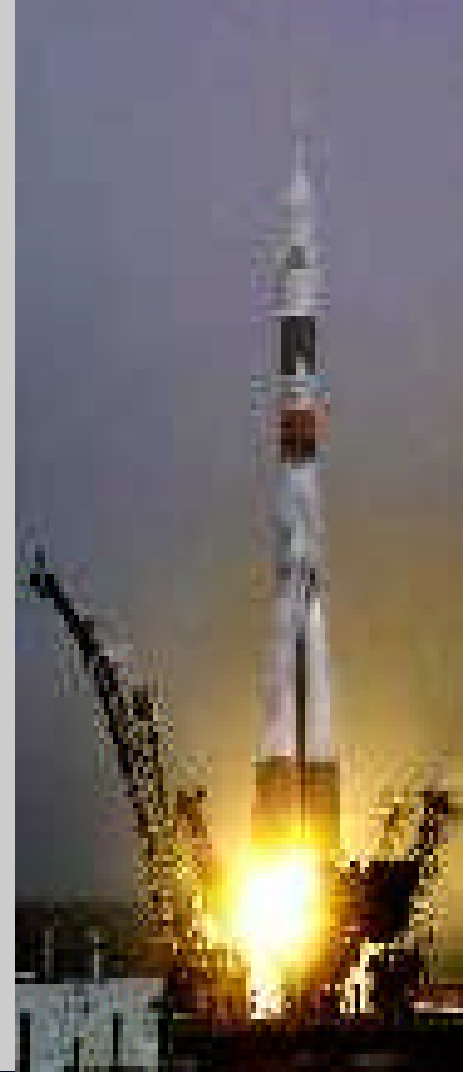
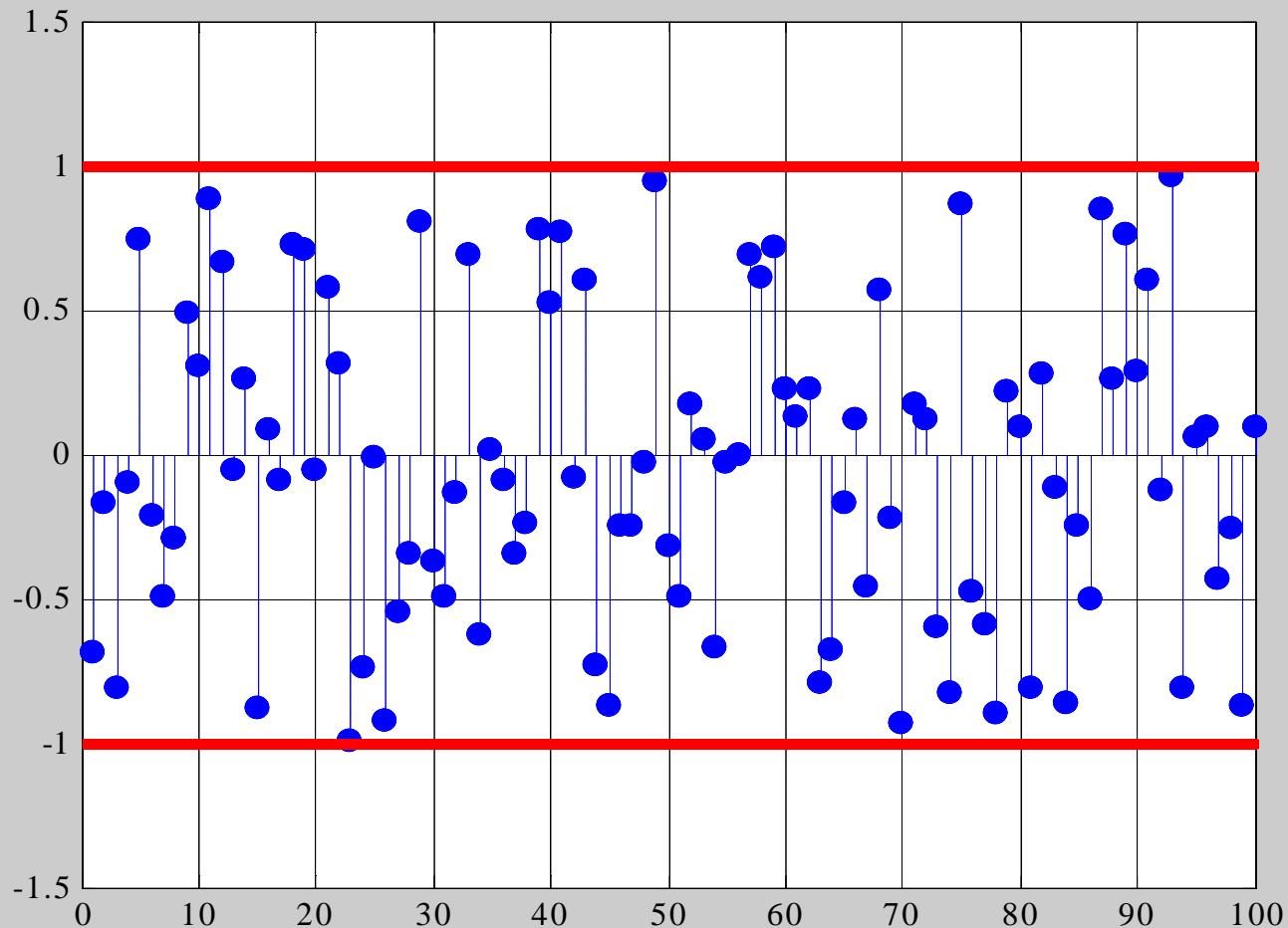


Tools for Robust Design

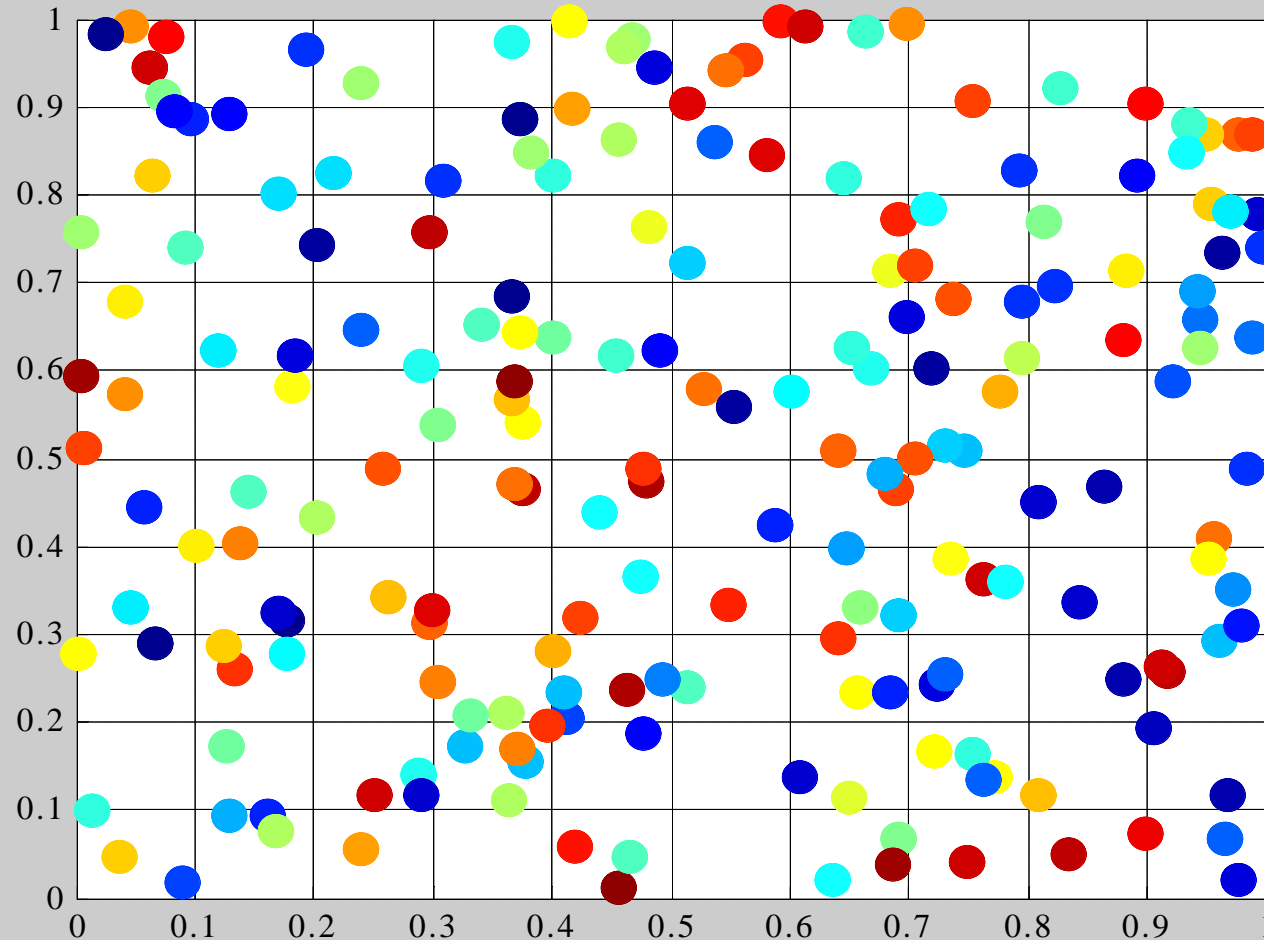
- Design Of Experiments
 - Exploits nonlinearities and interactions between noise & control parameters to reduce product performance variability
 - full factorial, fractional factorial, Monte-Carlo, LHC
- Response Surface Methods
 - Central Composite Design
 - Box-Behnken Design
- 6-sigma design
 - Identifying & qualifying causes of variation
 - Centering performance on specification target
 - Achieving Six Sigma level robustness on the key product performance characteristics with respect to the quantified variation



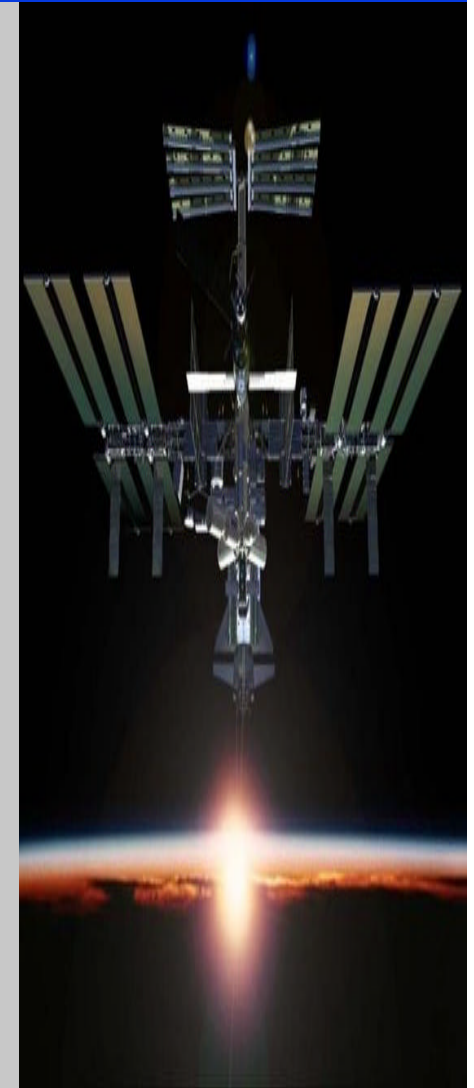
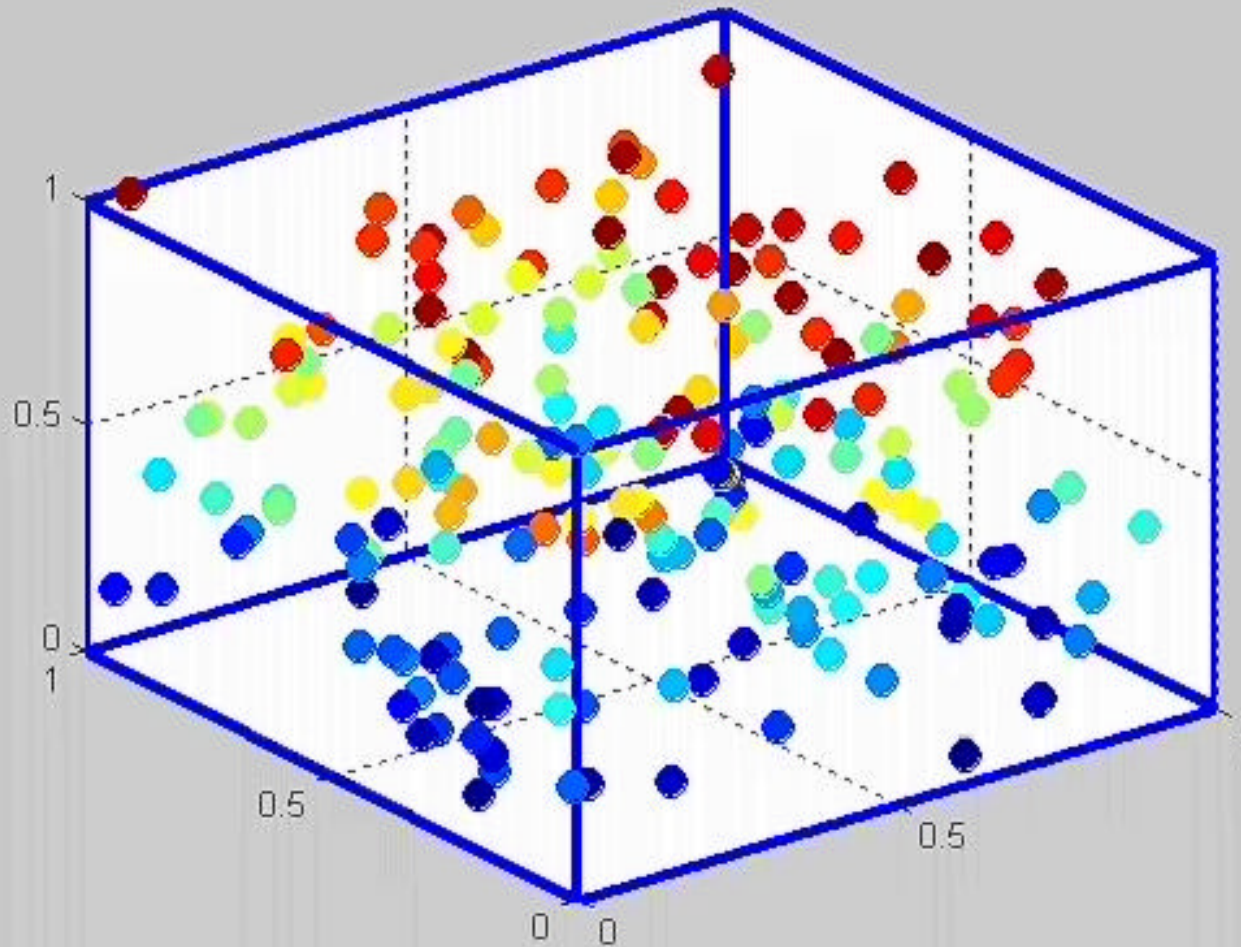
Design Exploration 1 Variable



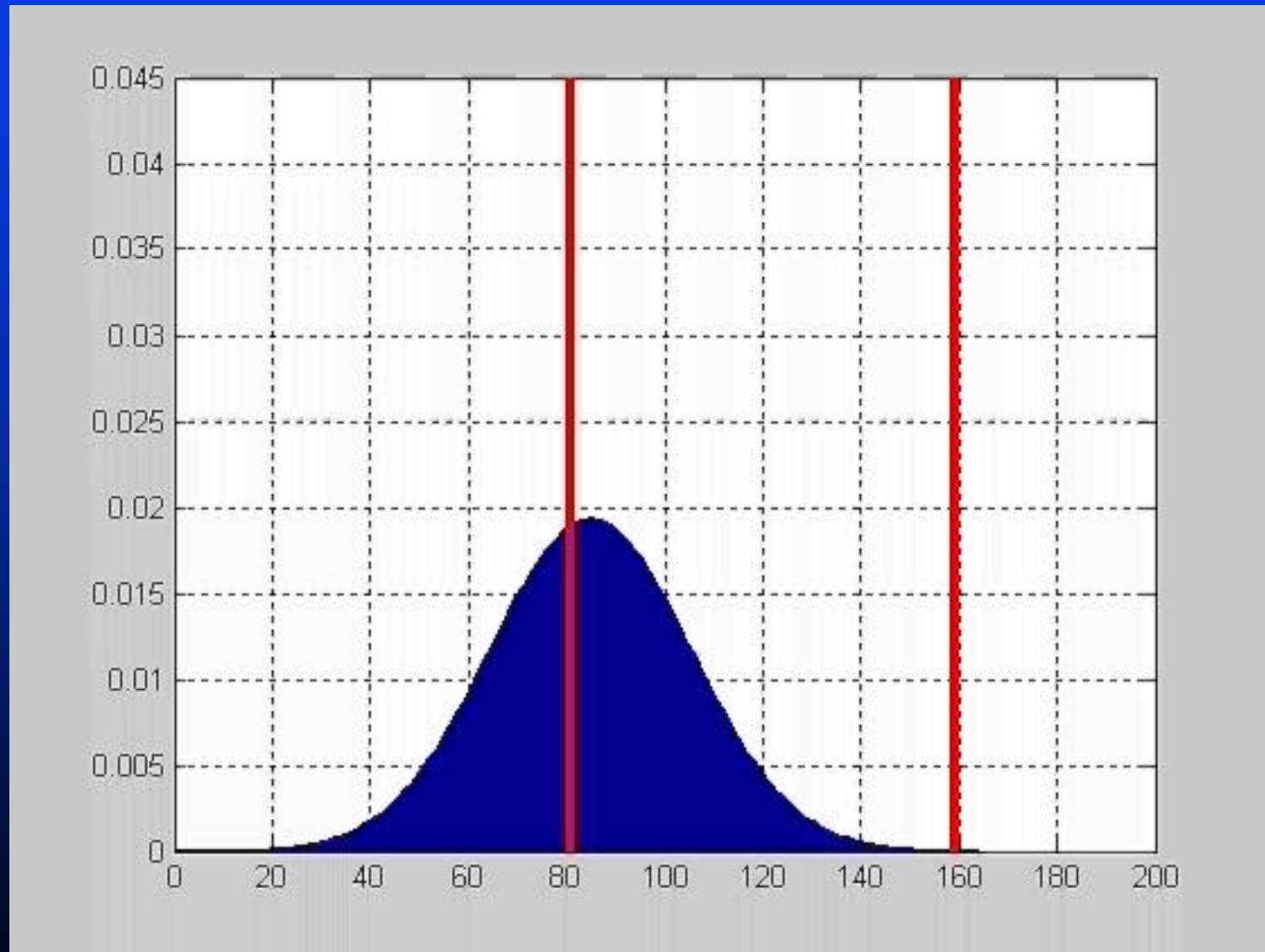
Design Exploration 2 Variables



Design Exploration 3 Variables



Shift and Squeeze





CETOL 6s

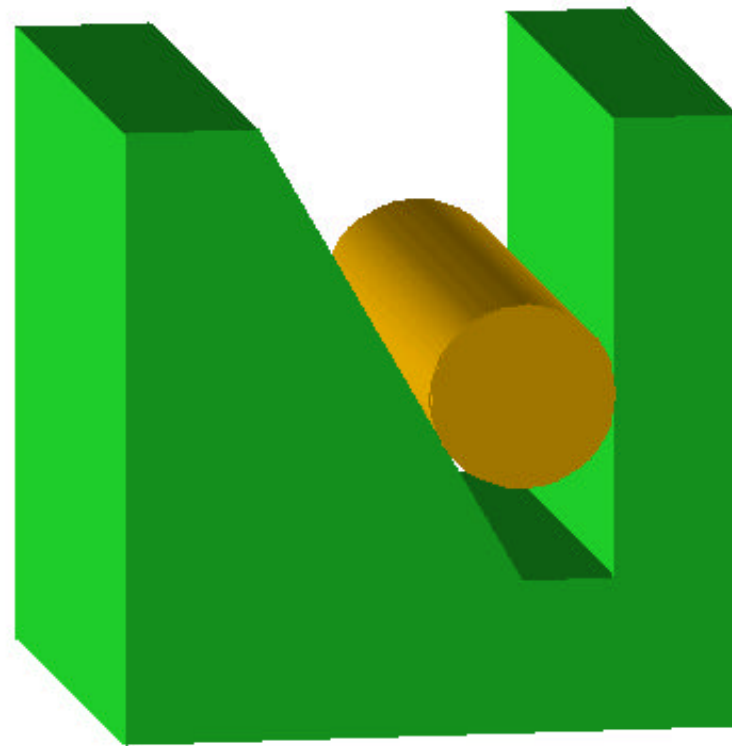
Mechanical Variation
Management System

3D Tolerance Analysis /
Allocation Software

Sensitivity and Statistical
Analysis

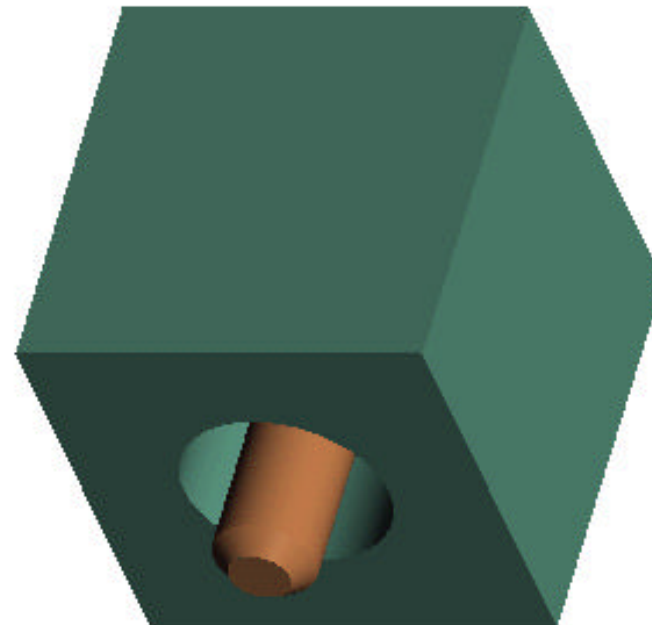
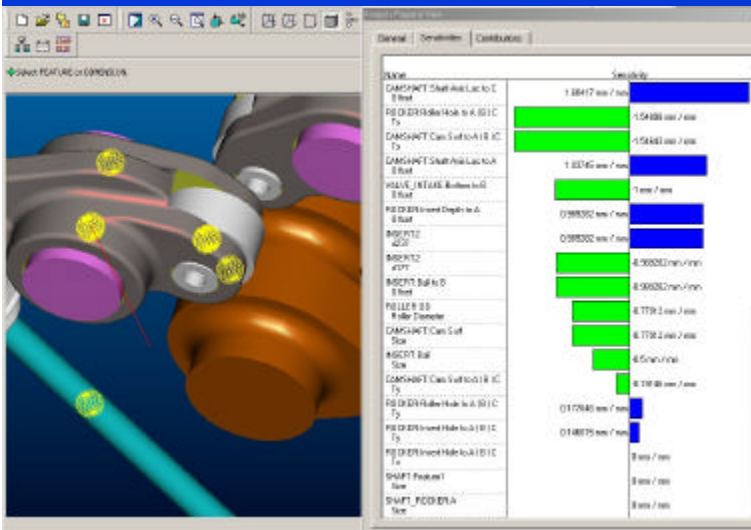
Leverages Mfg Process
Capability Data

Optimized for DFSS Experts
and Pro/E Users



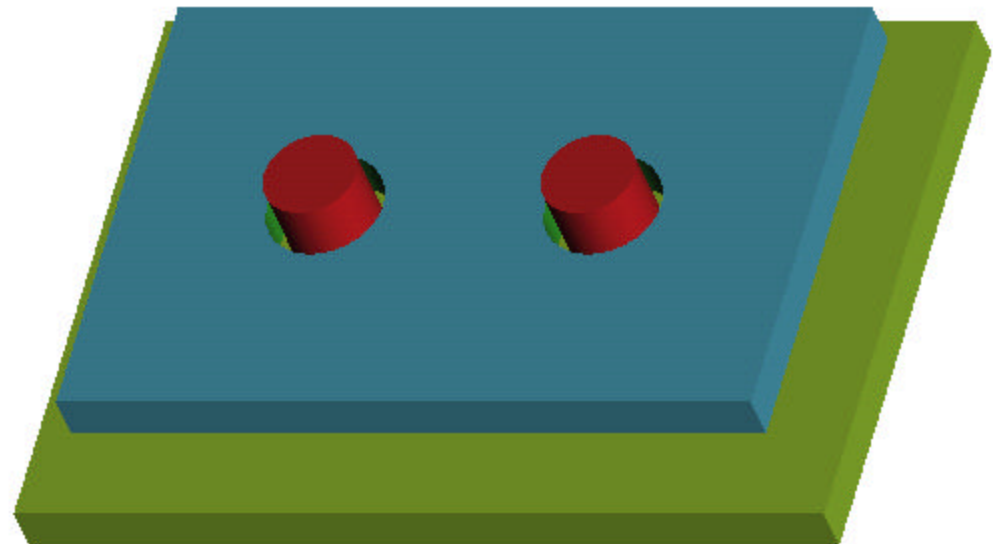
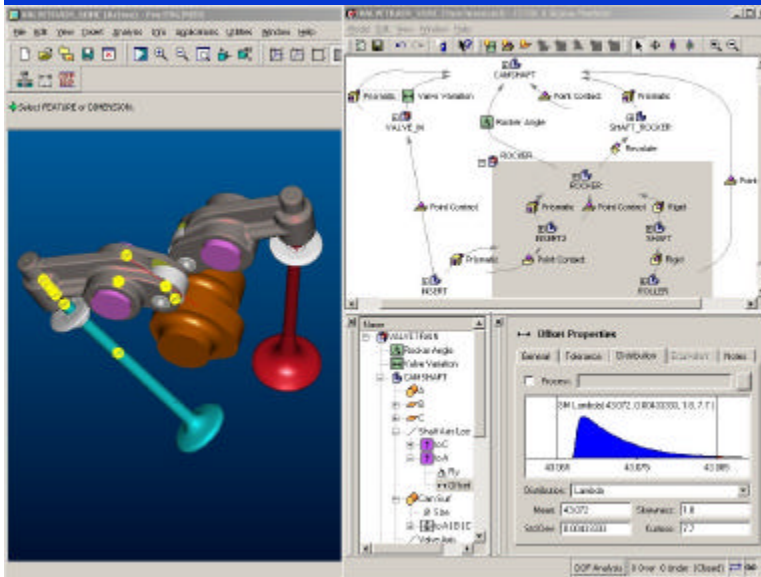
Sources of Assembly Variation: Multiple Configurations of Assembly

Tools like CE/TOL addresses the issue that one assembly constraint in Pro/E can have many configurations affecting variation

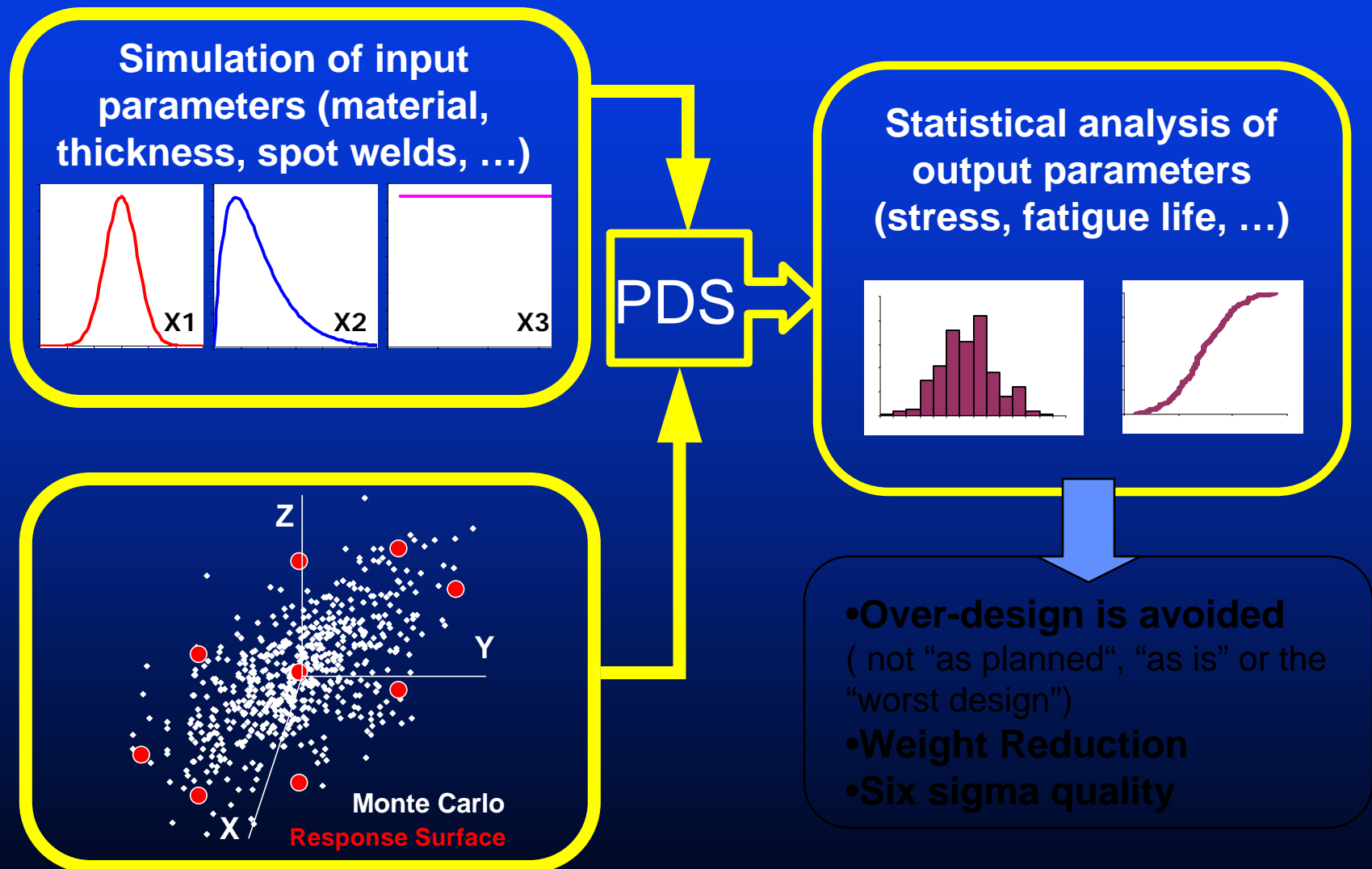


Sources of Assembly Variation: Fastened Interface Variation

- Higher level assembly constraints require unique representation
- CETOL recognizes full range of configurations



Statistical Design Performance Simulation



Probabilistic Analysis setup within ANSYS is SIMPLE

The screenshot illustrates the steps to set up a probabilistic analysis in ANSYS. The **ANSYS Main Menu** is open, showing the **Prob Design** option. The **Prob Design** dialog box is also open, showing the **-Analysis File-** and **-Prob Definitns-** sections. The **Define a Random Variable** dialog box is open, showing the **[PDUVAR] Define a Random Variable** section. The **Quantify Gaussian Distribution** dialog box is open, showing the **Parameters for GAUSSIAN Distribution** section. The **Carlo Simulation** dialog box is open, showing the **Settings for Monte Carlo Simulations** section.

ANSYS Main Menu

- Preferences ...
- Preprocessor >
- Solution >
- General Postproc >
- TimeHist Postpro >
- Topological Opt >
- Design Opt >
- Prob Design >
- Radiation Opt >
- Run-Time Stats >
- Session Editor ...
- Finish

Prob Design

- Analysis File-
 - Create ...
 - Assign ...
- Prob Definitns-
 - Random Input...
 - Plot ...
 - Inquire ...
 - Correl Field...
 - Correlation ...
 - Random Output...
- Prob Method-
 - Monte Carlo Sims..
 - Response Surface..
- Run >
- Response Surf-
 - Fit Resp Surf..
 - Plt Resp Surf..
 - Prn Resp Surf..
 - RS Simulation..
- Prob Results-
 - Statistics >
 - Trends >
 - Report >
- Prob Database-
 - Save ...
 - Resume ...
 - Clear & Reset..
 - Status

Define a Random Variable

[PDUVAR] Define a Random Variable

Name Select a Parameter

Quantify Gaussian Distribution

Parameters for GAUSSIAN Distribution

MEAN Mean value 0

SIGMA>0 Standard deviation 1

OK Cancel Help

Carlo Simulation

Settings for Monte Carlo Simulations

Sampling Method

☐ Direct Sampling

☒ Latin Hypercube

☐ User defined

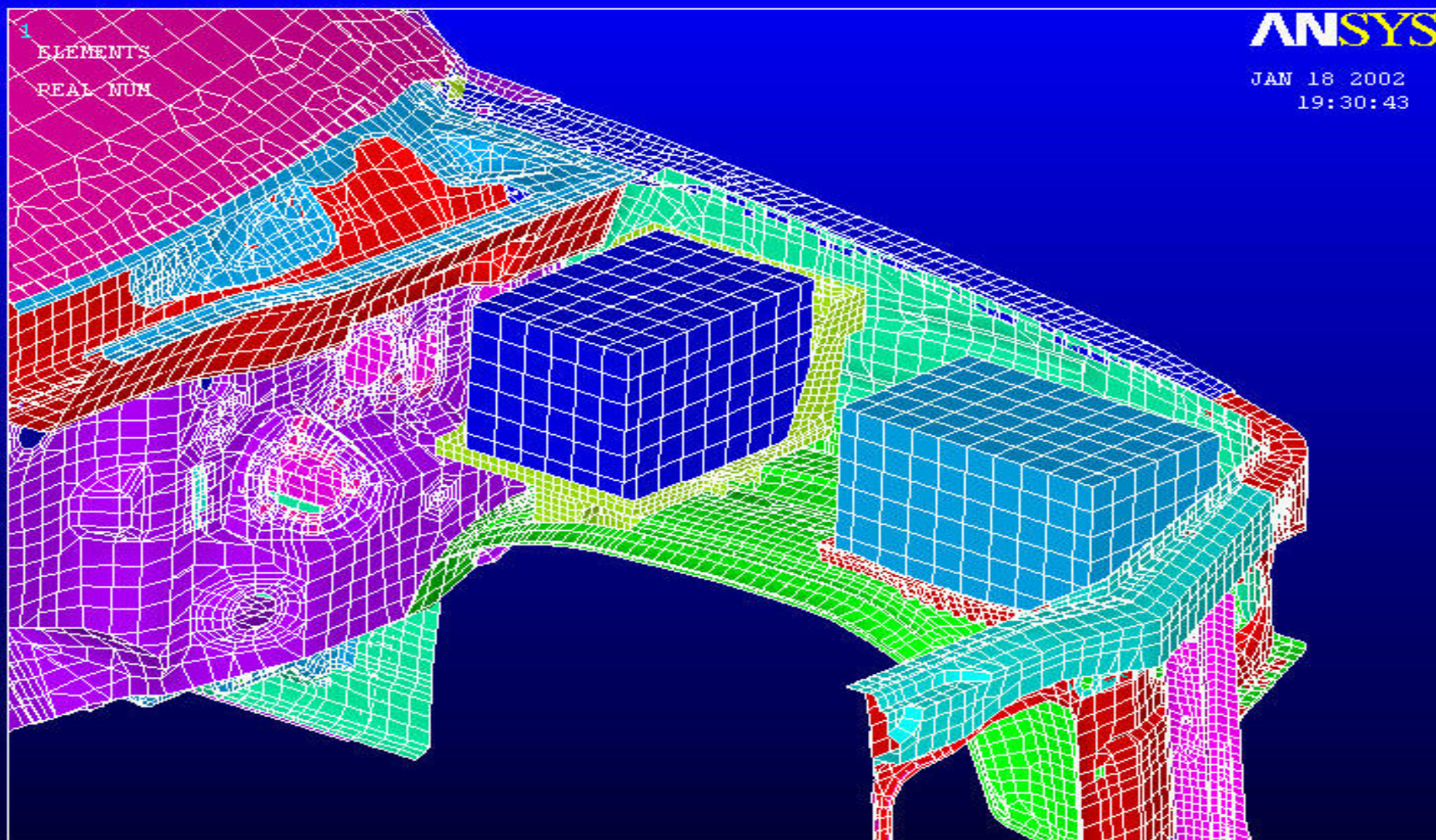
OK Cancel Help

Table of Probability Distributions:

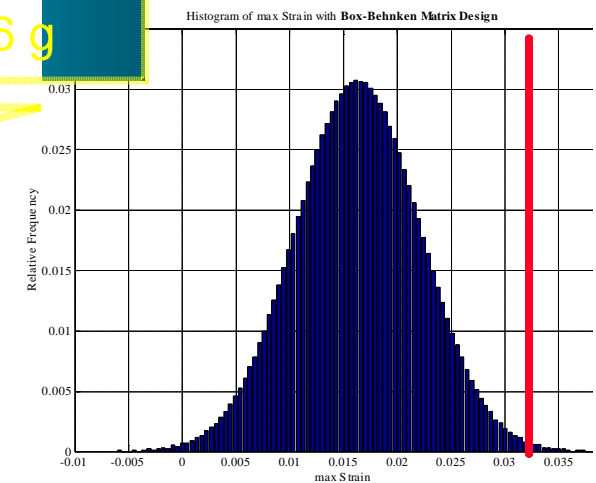
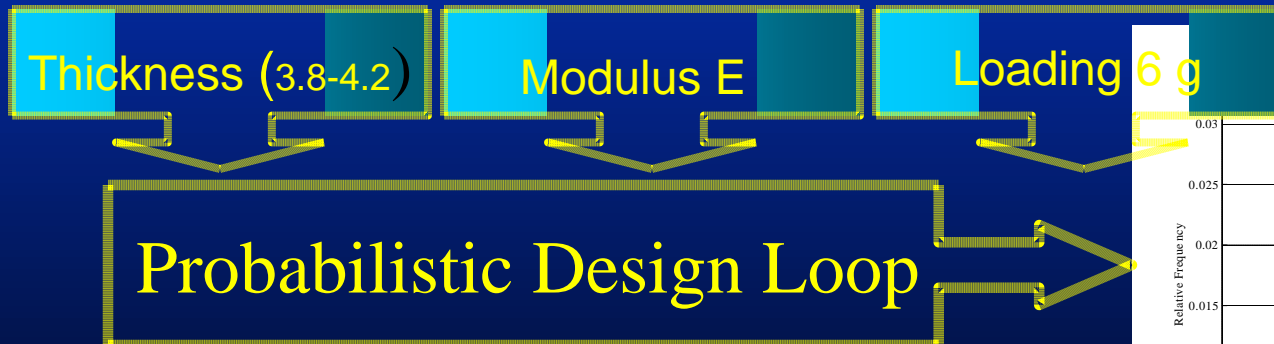
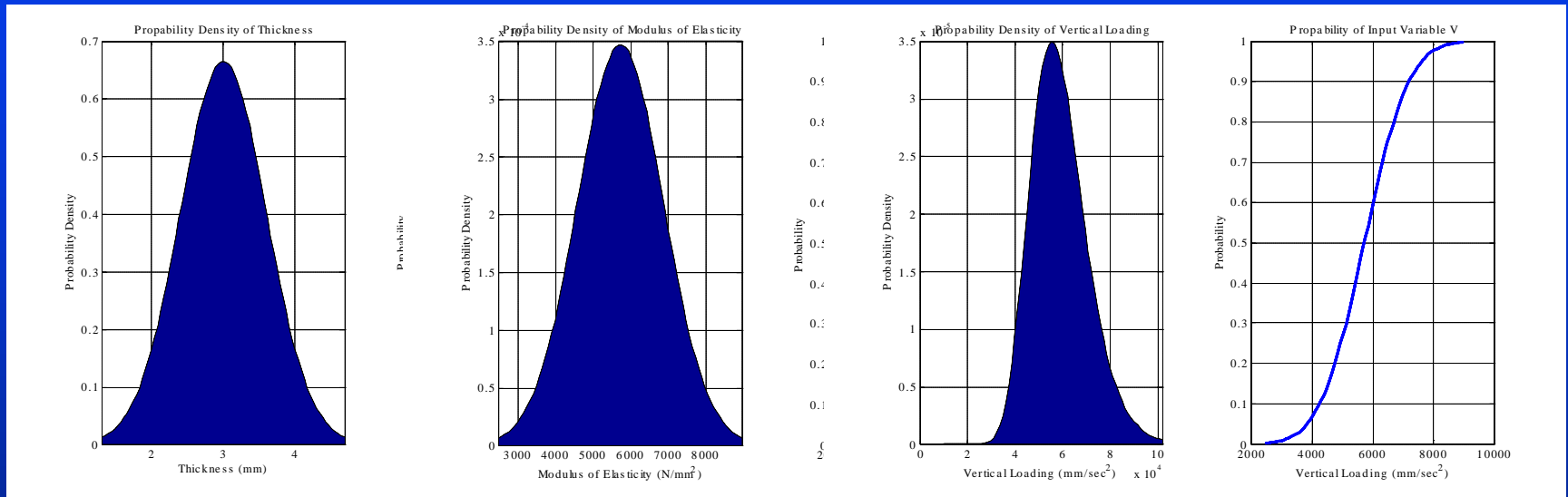
Gauss	GAUS
Trunc Gauss	TGAU
Lognormal 1	LOG1
Lognormal 2	LOG2
Triangular	TRIA
Uniform	UNIF
Exponential	EXPO
Beta	BETA
Gamma	GAMA
Null	WEIB

Functional Vehicles

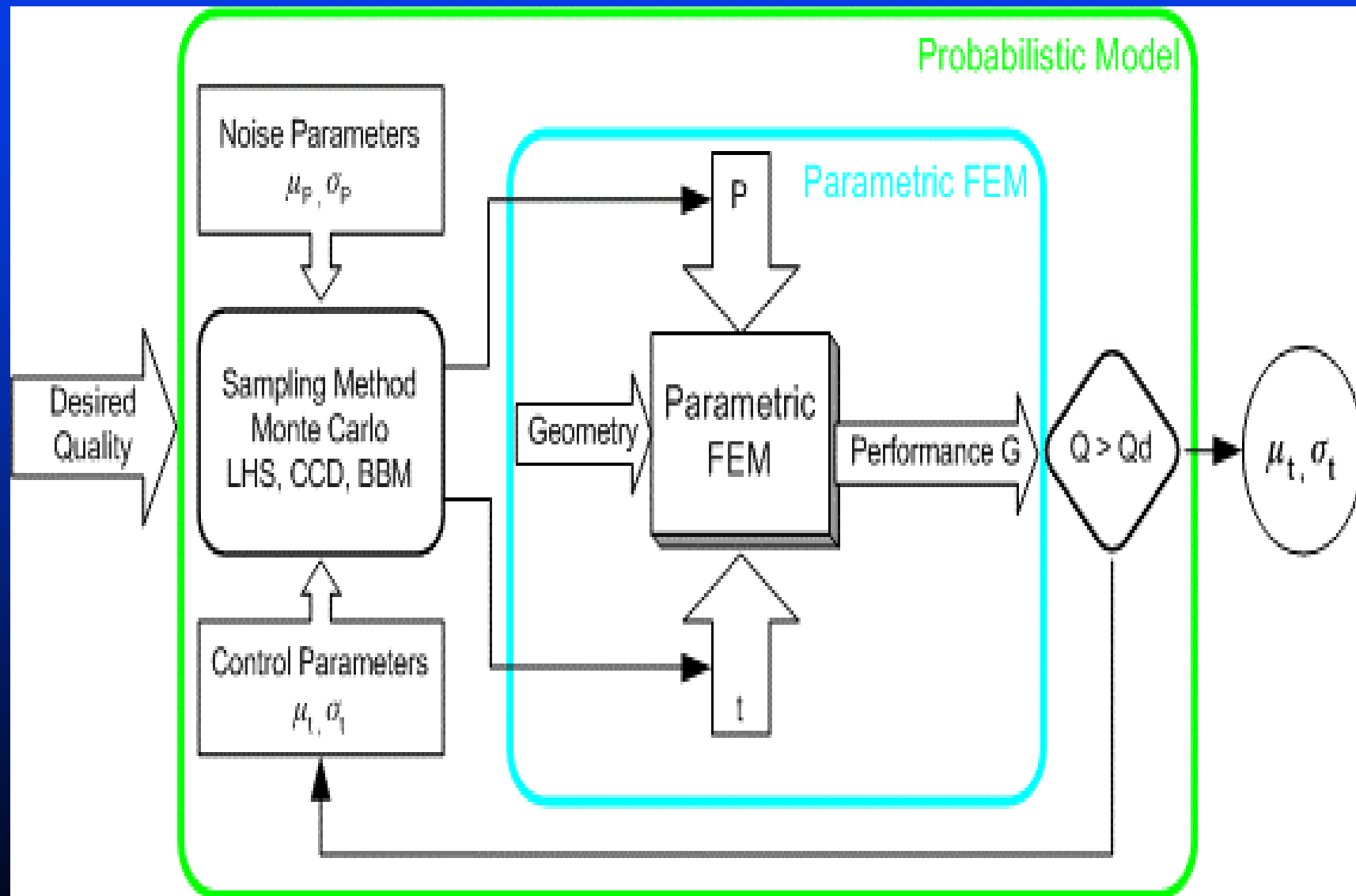
Automotive Example



Probability Distributions of input and output variables



Reliability Based Optimization



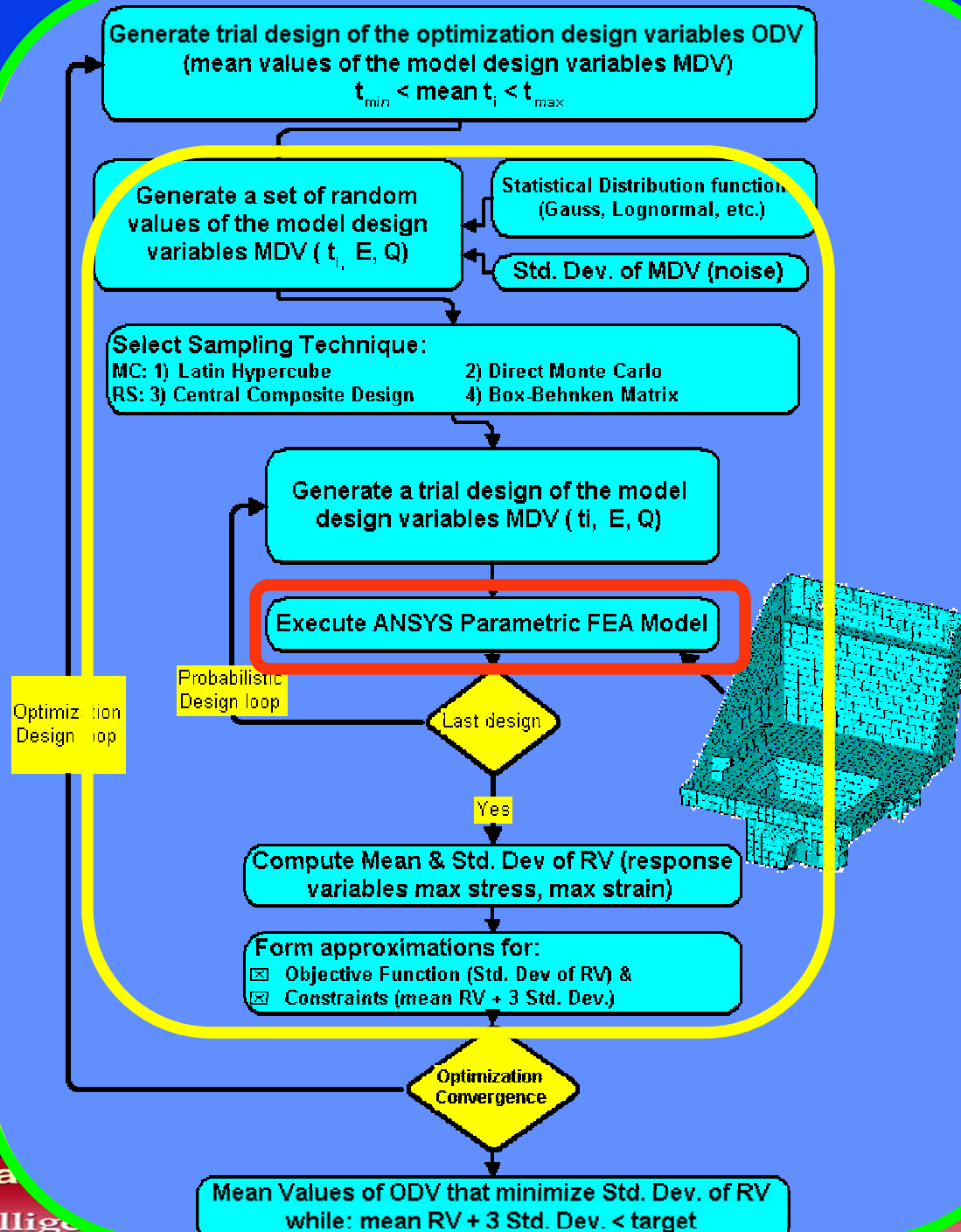
RBO Workflow

Automatic, No Manual iteration:
CAD -> Meshing -> FEA

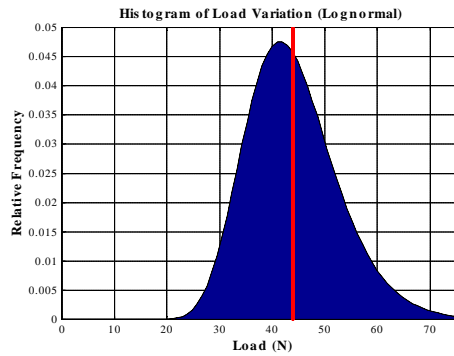
Probabilistic Design Loop

Optimization Loop with reliability constraints

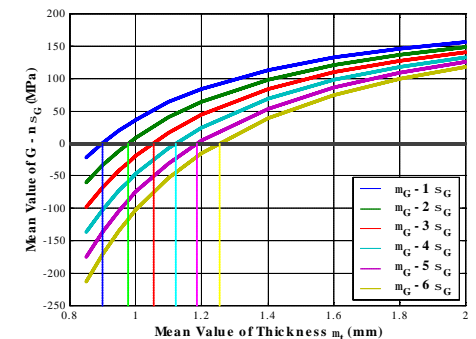
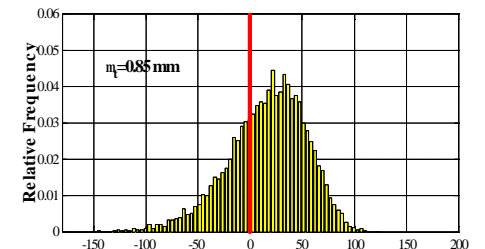
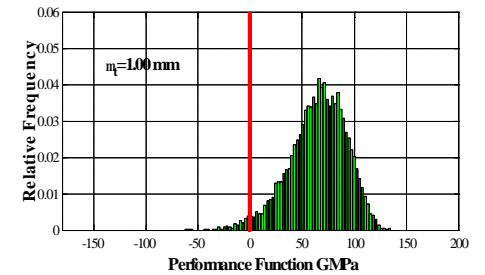
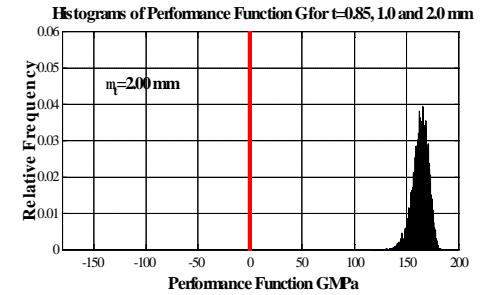
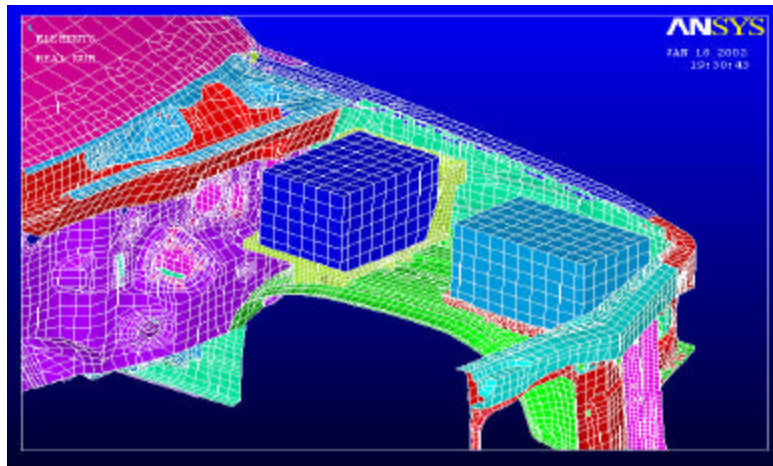
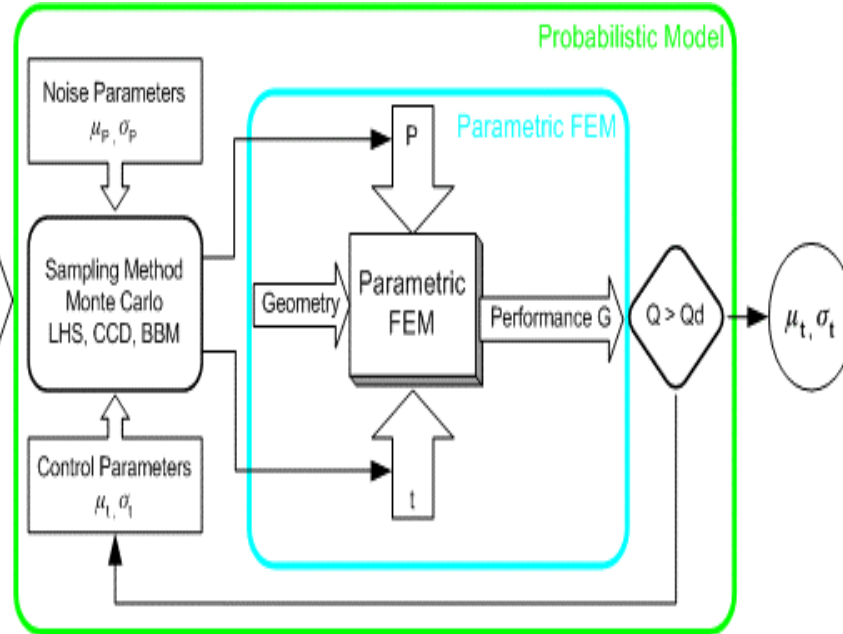
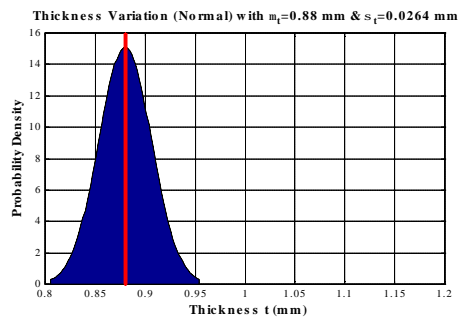
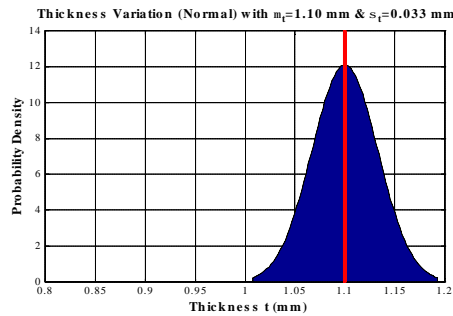
Deterministic Optimum designs could lead to unreliable or even catastrophic designs



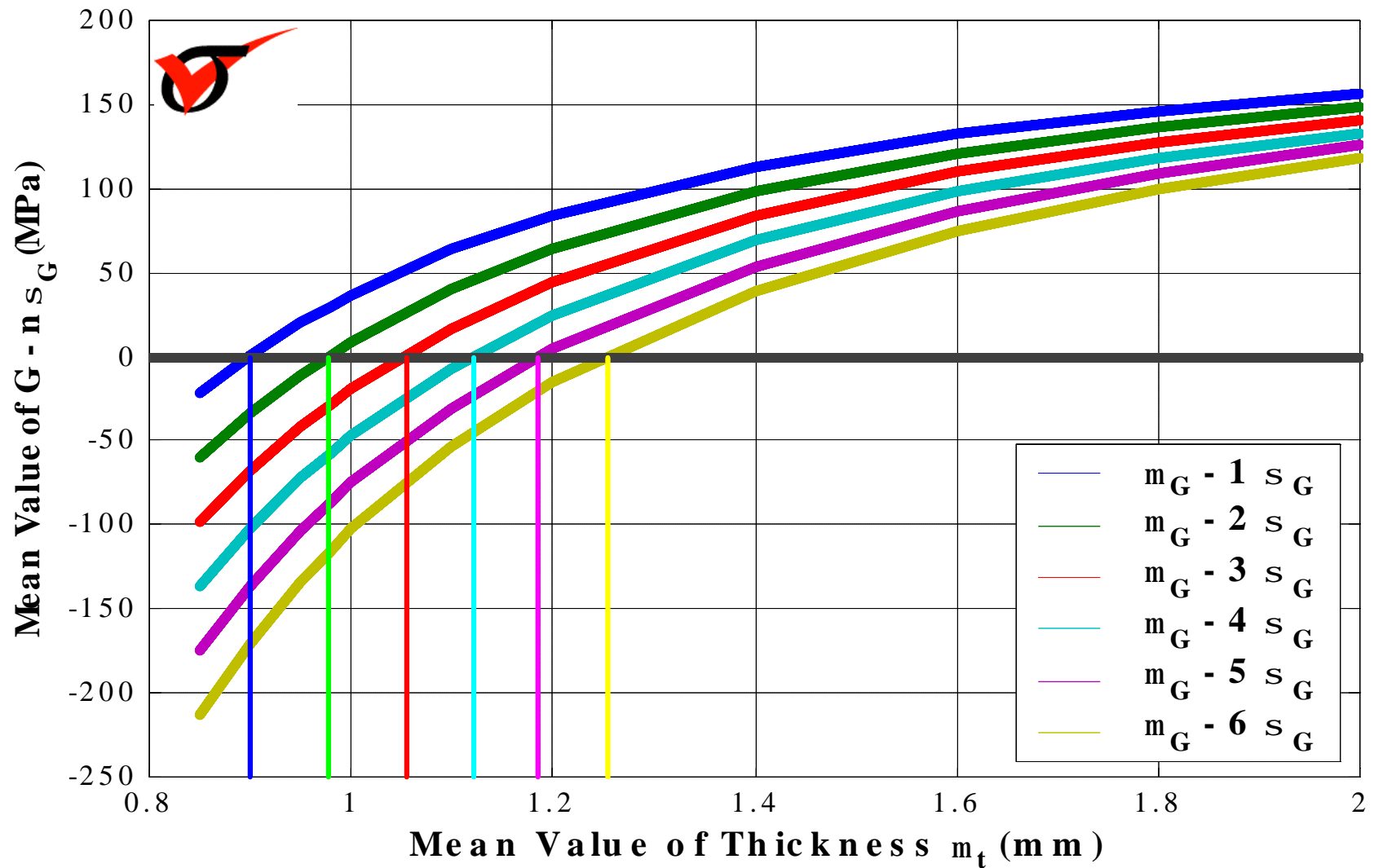
Workflow for Robust Design System



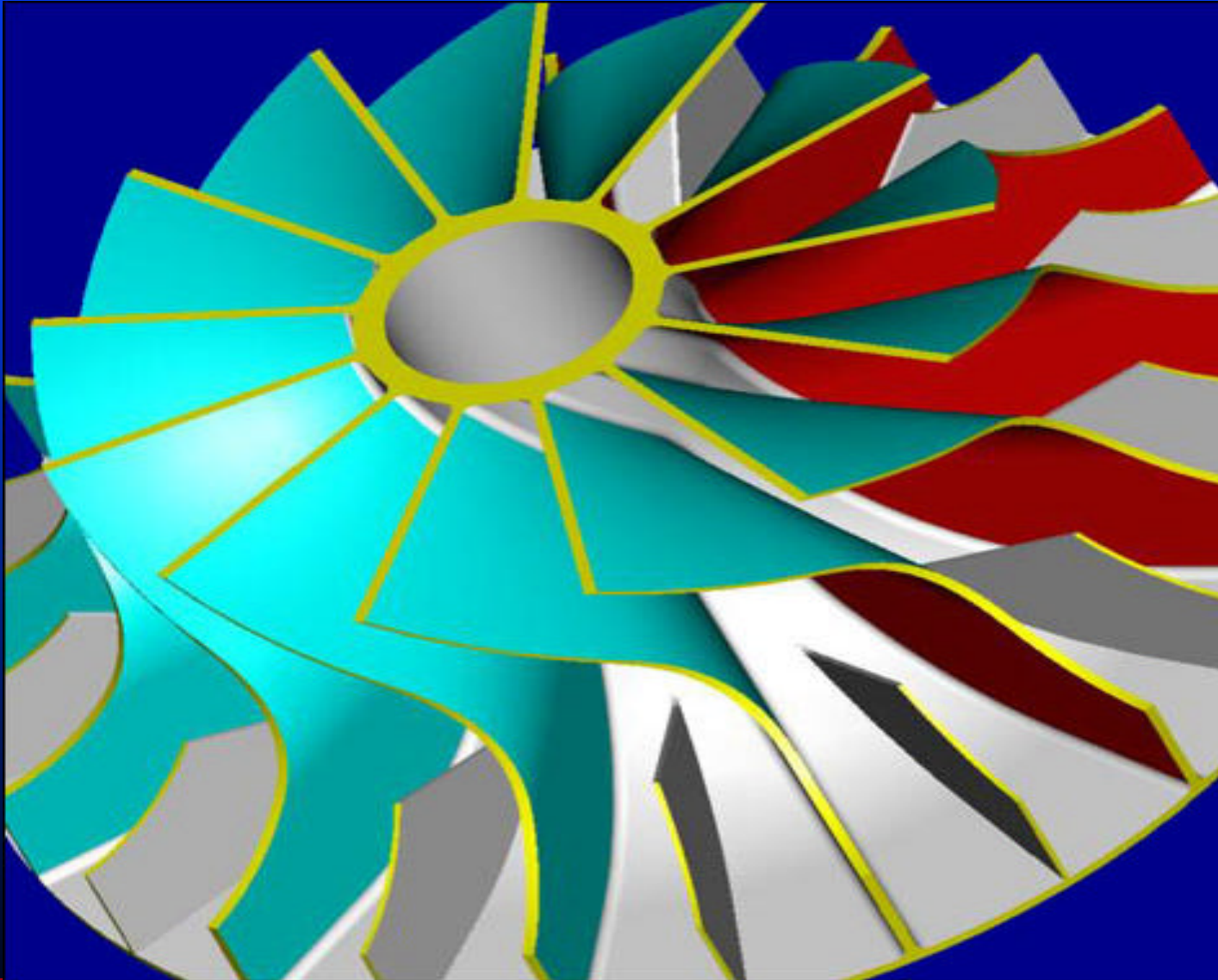
Desired Quality



Performance Function $G = S_{ult} - S_{max}$



PDS for CAD Design Variables



Behavioral Modeling External Analysis – ANSYS_PDS

ANALYSIS

Feature Element Tree

Tree

Elements

Info

Analysis

Name

Type

RegenRequest

ANALYSIS1

Type

Measure

Curve Analysis

UDA

External Analysis

Model Analysis

Surf Analysis

Relation

Excel Analysis

RegenRequest

Always

Read only

Only DesignStudy

Back

Next

✓

✗

⚙

External Analysis

Type

AndreasBMX

Definition

Analysis UI

Results

Compute

Info

Saved Analyses

Name

Retrieve

Delete

Close

External Analysis

Type

AndreasBMX

Definition

Analysis UI

Results

MEAN_FREQ1 = 334.051235
STDV_FREQ1 = 11.868095
COV_FREQ1 = 0.035528
PROB_FREQ1_INT1 = 0.000000
PROB_FREQ1_INT2 = 0.000000
PROB_FREQ1_INT3 = 0.000000
MEAN_FREQ2 = 416.399323
STDV_FREQ2 = 14.793738
COV_FREQ2 = 0.035528
PROB_FREQ2_INT1 = 0.000000
PROB_FREQ2_INT2 = 0.000000
PROB_FREQ2_INT3 = 0.000000
MEAN_FREQ3 = 524.070069
STDV_FREQ3 = 18.619039
COV_FREQ3 = 0.035528
PROB_FREQ3_INT1 = 0.000000
PROB_FREQ3_INT2 = 0.000000
PROB_FREQ3_INT3 = 0.000000
MEAN_FREQ4 = 785.754546
STDV_FREQ4 = 27.916103

Compute

Info

ANALYSIS

Feature Element Tree

Tree

Elements

Info

Type

RegenRequest

Definition

Result params

Result params

Create	Param name	Description
YES	MEAN_FREQ1	PDS Parameter
YES	STDV_FREQ1	PDS Parameter

Create

YES

NO

Param name

MEAN_FREQ1

Back

Next

✓

✗

⚙

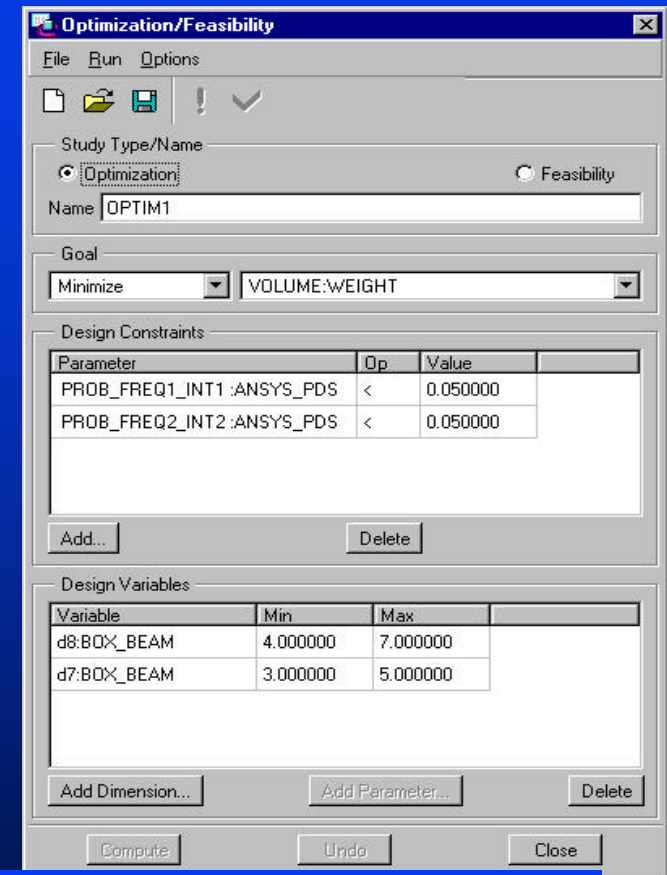
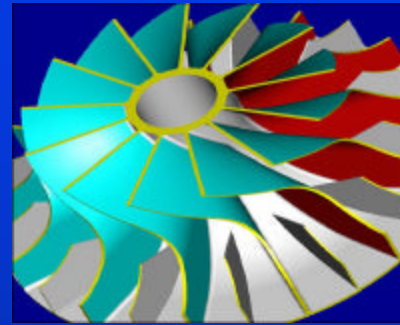
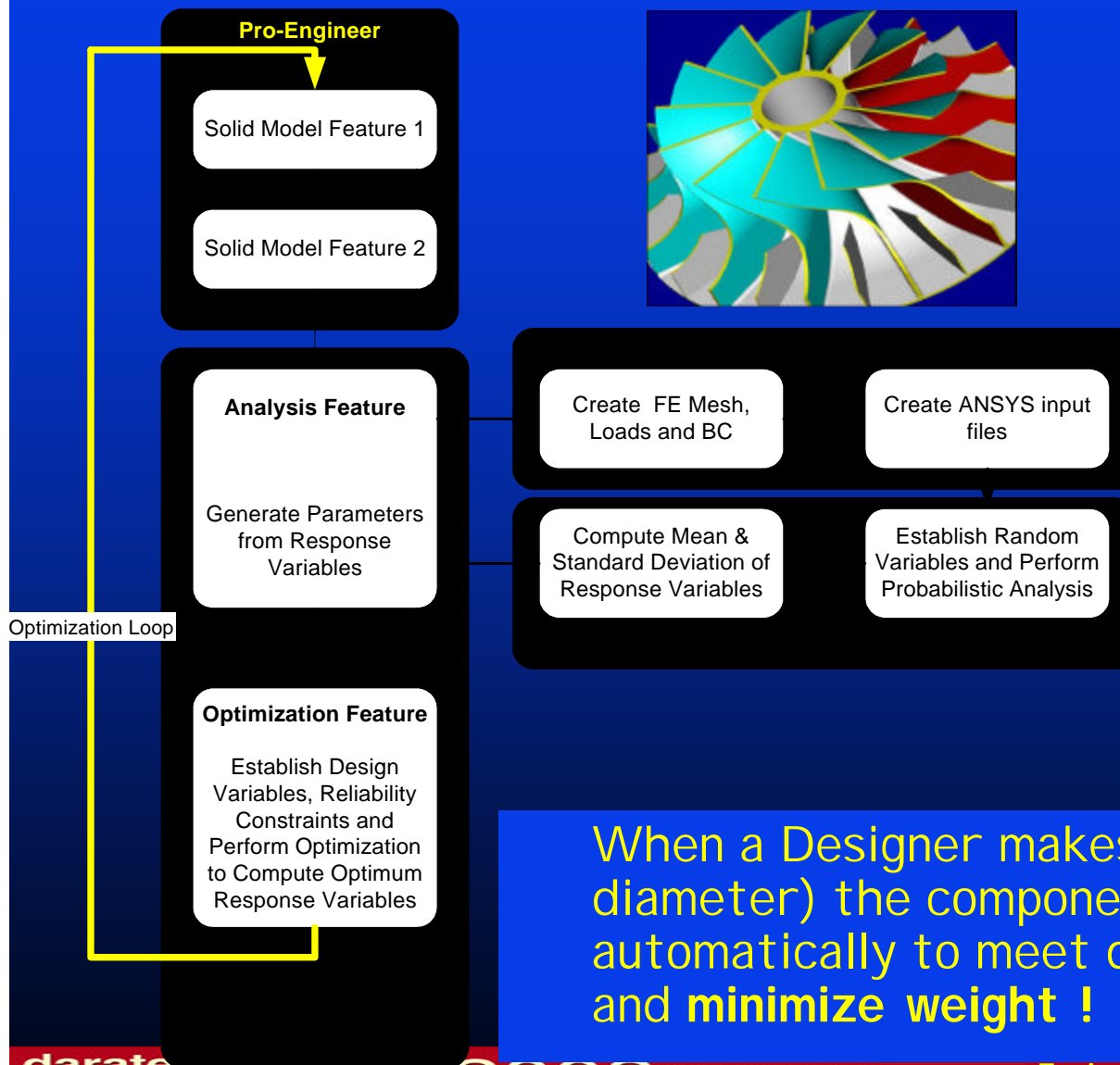
BMX External Analysis & Optimization Features

The screenshot displays the BMX software interface with the following components:

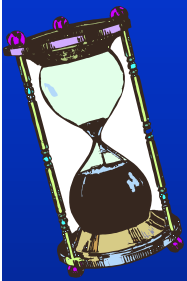
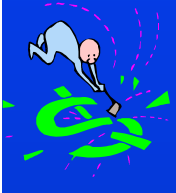
- Model Tree:** A hierarchical list of the model's structure.
 - BOX_BEAM.PRT
 - RIGHT
 - TOP
 - FRONT
 - PRT_CSYS_DEF
 - Protrusion id 39
 - WEIGHT
 - ANSYS_PDS
 - RELIABILITY_OPTIMIZATION
 - Insert Here
- Optimization/Feasibility Dialog Box:** A window for configuring optimization settings.
 - Study Type/Name:** Optimization (selected), Feasibility
 - Name:** OPTIM1
 - Goal:** Minimize (selected), VOLUME:WEIGHT
 - Design Constraints:**

Parameter	Op	Value
PROB_FREQ1_INT1:ANSYS_PDS	<	0.050000
PROB_FREQ2_INT2:ANSYS_PDS	<	0.050000
 - Design Variables:**

Variable	Min	Max
d8:BOX_BEAM	4.000000	7.000000
d7:BOX_BEAM	3.000000	5.000000



When a Designer makes a change (i.e. hole diameter) the component thickness updates automatically to meet desired quality criteria and **minimize weight !**



- Productivity improvements up to 90%
- Improve quality (6 σ) and system level performance (MDO)
- Enables integrated product development system
- Captures and utilizes design knowledge in early design stages
- Greater Utilization of Engineering Talent
 - Drudgery of multiple simulation runs passed onto computer
 - Greater portion of the engineer's time spent on fundamental engineering
 - More time to understand customer requirements and focus on design constraint definition

**Create a Vision,
Adopt it,
Adapt to Achieve it**

